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Indian Standard

EXPRESSION OF THE PROPERTIES OF SPECTRUM ANALYZERS

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Indian Standard

EXPRESSION OF THE PROPERTIES OF SPECTRUM ANALYZERS

Electronic Measuring Equipment Sectional Committee, LTDC 21

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Indian Standard

EXPRESSION OF THE PROPERTIES OF SPECTRUM ANALYZERS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 12 November 1984, after the draft finalized by the Electronic Measuring Equipment Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 The object of this standard is to lay down uniform methods of expression of the properties of spectrum analyzers and more particularly:

a) to define special terminology and catalogue data related to these type of apparatus; and

b) to specify conditions and methods for testing these types of apparatus in order to verify compliance with properties claimed or specified by the manufacturer.

0.3 This standard is based, without any technical deviation, on IEC Pub 714-1981 ' Expression of the properties of spectrum analyzers ', issued by International Electrotechnical Commission (IEC).

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard is applicable to instruments known as nonreal-time spectrum analyzers (hereinafter called 'analyzers').

1.1.1 These instruments perform analysis of the power distribution of a signal by a sampling process, such as the following:

*Rules for rounding off numerical values (*revised*).

a) Swept front end — Superheterodyning in which the first local oscillator is swept.

b) Swept IF — Superheterodyning in which other than the first local oscillator is swept.

c) Video detector/tunable filter — Analysis is accomplished by scanning the input filter across the signal in proportion to the CRT horizontal deflection with the detector output providing the vertical deflection.

NOTE — Instruments known as real-time analyzers perform a continuous analysis of the incoming signal with the time sequence of events preserved between input and output. This standard is not applicable to those instruments.

2. TERMINOLOGY

2.0 For the purpose of this standard, the definitions given below shall apply. The characteristics whose definitions are given consist of two types — main and general. Main characteristics are measurable as described in **4**. They are usually specified. Examples are residual FM, frequency span, or sensitivity. Additional (general) characteristics, such as line spectrum or envelope display are used in technical documentation when required, depending on the purpose of the apparatus.

For terms related to display, such as tune base or single sweep, *see* IS : 11018 (Part 1)-1984*.

2.1 General Terms

2.1.1 *Spectrum Analyzer* — An apparatus which is generally used to display the power/amplitude distribution of an incoming signal as a function of frequency.

NOTE — Such an apparatus is useful in analyzing the charateristics of repetitive electrical waveforms in general, since by repetitively sweeping through the frequency range of interest it will display all components of the signal. The apparatus is intended to be used for investigating stationary signals, the spectrum of which practically does not change during sequential analysis.

2.1.2 *Centre Frequency* — That frequency which corresponds to the centre of a frequency span, expressed in hertz (Hz).

2.1.3 *Effective Frequency Range* — That range of frequency range over which the frequency can be adjusted, expressed in hertz (Hz).

2.1.4 *Frequency Band* — A part of the effective frequency range over which the frequency can be adjusted, expressed in hertz (Hz).

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*Expression of the properties of cathode-ray oscilloscopes : Part 1 General.

2.1.5 *Full Band Span* — A mode of operation in which the spectrum analyzer scans an entire frequency band.

2.1.5.1 *Multiband span* — A mode of operation in which the spectrum analyzer scans more than one frequency band.

2.1.6 *Zero Span* — A mode of operation in which the frequency span is reduced to zero.

2.1.7 *Envelope Display* — The display produced on a spectrum analyzer when the static or dynamic resolution bandwidth is greater than the spacing of the individual frequency components.

2.1.8 *Line Display* — The display produced on a spectrum analyzer when the static or dynamic resolution bandwidth is less than the spacing between the amplitudes of the individual frequency components.

2.1.9 *Line Spectrum* — A spectrum composed of signal amplitudes of the discrete frequency components.

2.1.10 *Maximum Input Power*

2.1.10.1 *Without degradation* — The maximum power applied at the input which will not cause degradation of the instrument characteristics.

2.1.10.2 *Without damage* — The maximum power applied at the input which will not damage the instrument.

2.1.11 *Intermodulation Spurious Response (or Intermodulation Distortion)* — An unwanted spectrum analyzer response resulting from the mixing of the *n*th order frequencies, due to non-linear elements of the spectrum analyzer, the resultant unwanted response being displayed.

2.1.12 *Baseline Clipper* — A means of changing the relative brightness between the signal and baseline portion of the display.

2.1.13 *Pulse Stretcher* — A pulse shaper that produces an output pulse, whose, duration is greater than that of the input pulse, and whose amplitude is proportional to that of the peak amplitude of the input pulse.

2.1.14 *Signal Identifier* — A means to identify the spectrum of the input signal when spurious responses, generated inside the instrument, are possible.

2.1.15 *Video Filter* — A post-detection low-pass filter.

2.1.16 *Scanning Velocity* — Frequency span divided by sweep time and expressed in hertz per second.

2.2 Terms Related to Frequency

2.2.1 *Display Frequency* — The input frequency as indicated by the spectrum analyzer and expressed in hertz.

2.2.2 *Frequency Span* — The magnitude of the frequency band displayed, expressed in hertz for a full scan or hertz per division of the full scan.

2.2.3 *Frequency Linearity Error* — The error of the relationship between the frequency of the input signal and the frequency displayed (expressed as a ratio).

2.2.4 *Frequency Drift* — Gradual shift or change in displayed frequency due to internal changes in the spectrum analyzer, and expressed in hertz per unit of time, or influence quantity where other conditions remain constant.

2.2.5 *Residual FM* — Short-term displayed frequency instability or jitter due to instability in the spectrum analyzer local oscillators, given in terms of peak-to-valley frequency deviation and expressed in hertz or percent of the displayed frequency.

2.2.6 *Impulse Bandwidth* — The displayed spectral amplitude level of an applied pulse divided by its spectral voltage density level which is assumed to be flat within the passband.

2.2.7 *Dynamic (Displayed) Resolution* — The frequency separation of two responses of equal amplitude which merge with a -3 decibel (dB) notch.

2.2.8 *Dynamic (Displayed) Skirt Resolution* — The frequency separation of two responses of unequal amplitude (having a specified amplitude ratio) when the notch formed between them is -3 decibels (dB) down from the smaller response.

2.2.9 *Static (Amplifier) Resolution Bandwidth* — The specified bandwidth of the spectrum analyzer's response to a cw signal, if sweep time is kept substantially long.

NOTE — This bandwidth is the frequency separation of two down points, usually -3 dB or -6 dB, on the response curve, if it is measured either by manual scan (true static method) or by using a very low speed (quasi-static method).

2.2.10 *Dynamic (Amplifier) Resolution Bandwidth* — The apparent resolution bandwidth when sweep time is relatively short. It is related to the static resolution bandwidth by the following formula:

$$B_{d} = \sqrt{B_{s}^{2} + K_{1}\left(\frac{S}{\Delta t \, B_{s}}\right)}$$

where

B_d = dynamic resolution bandwidth;

B_s = static resolution bandwith (*see* **2.2.9**);

S = frequency span (*see* **2.2.2**);

Δt = sweep time; and

K_1 = constant factor (usually 0·195 for Gaussian-type filters).

2.2.11 *Optimum Dynamic Resolution Bandwidth* — The minimum obtainable value of dynamic resolution bandwidth for each combination of frequency span and sweep time.

NOTE — Theoretically, it is related to the optimum static resolution bandwidth by the formula:

$$B_{od} = \sqrt{2 B_{os}} \text{ where } B_{os} = K_2 \sqrt{\frac{S}{\Delta t}}$$

where

B_{od} = optimum (minimum) dynamic resolution bandwidth;

B_{os} = setting of (optimum) static resolution bandwidth to obtain B_{od};

S = frequency span (*see* **2.2.2**);

Δt = sweep time; and

K_2 = constant factor (0·665) for Gaussian-type (filters). Approximately,

$$B_{od} \simeq \sqrt{\frac{S}{\Delta t}}$$

2.2.12 *Shape Factor* — The ratio of the frequency separation of the two −60 dB down points in the response curve to the static resolution bandwidth.

2.2.13 *Zero Pip* — An output indication which corresponds to zero input frequency.

2.3 Terms Related to Amplitude

2.3.1 *Deflection Coefficient* — The ratio of the input signal magnitude to the resultant output indication.

NOTE — The ratio may be expressed in terms of volts (rms) per division, decibels per division, watts per division, or any other specified unit.

2.3.2 *Display Reference Level* — A designated vertical position representing a specified input level.

NOTE — The level may be expressed in decibels referred to 1 mW [dB (1 mW)], volts or any other suitable unit.

2.3.3 *Sensitivity* — Measure of a spectrum analyzer's ability to display minimum level signals, at a given IF bandwidth, display mode, and any other influencing factors, and expressed in decibels referred to 1 mW [dB (1 mW)].

2.3.4 *Input Signal Level Sensitivity* — The input signal level that produces an output equal to twice the value of the average noise alone.

NOTE — This may be a power or voltage relationship, but should be so stated.

2.3.5 *Equivalent Input Noise Sensitivity* — The average level of a spectrum analyzer's internally generated noise referred to the input.

2.3.6 *Display Flatness* — The unwanted variation of the displayed amplitude over a specified frequency span, expressed in decibels.

NOTE — Display flatness is closely related to frequency response. The main difference is that the spectrum display is not re-centred.

2.3.7 *Peak-to-Valley Display Flatness* — The display flatness measured peak-to-valley.

2.3.8 *Relative Display Flatness* — The display flatness measured relative to the display amplitude at a fixed frequency within the frequency span, expressed in decibels.

2.3.9 *Frequency Response* — The unwanted variation of the displayed amplitude over a specified centre frequency range, measured at the centre frequency, expressed in decibels.

2.3.10 *Peak-to-Valley Frequency Response* — The frequency response measured peak-to-valley.

2.3.11 *Relative Frequency Response* — The frequency response measured relative to the displayed amplitude at a fixed centre frequency within the specified range.

2.3.12 *Display Law* — The mathematical law that defines input-output functions of the x and y axes of the instrument.

NOTE — The following cases apply:

a) Linear — A display in which the scale divisions are a linear function of the input signal voltage.

b) Square law — A display in which the scale divisions are a linear function of the input signal power.

c) Logarithmic — A display in which the scale divisions are a logarithmic function of the input signal voltage.

2.3.13 *Dynamic Range* — The maximum difference between the levels of two signals simultaneously present at the input which can be measured to a specified accuracy.

2.3.14 *Harmonic Dynamic Range* — The maximum difference between the levels of two harmonically related sinusoidal signals simultaneously present at the input which can be measured with a specified accuracy.

2.3.15 *Nonharmonic Dynamic Range* — The maximum difference between the levels of two nonharmonically related sinusoidal signals simultaneously present at the input which can be measured with a specified accuracy.

2.3.16 *Display Dynamic Range* — The maximum difference between the levels of two nonharmonically related sinusoidal signals each of which can be totally displayed and simultaneously measured with a specified accuracy.

2.3.17 *Gain Compression* — Maximum input level where the scale linearity error is below that specified.

2.3.18 *Spurious Response* — A response of a spectrum analyzer wherein the displayed frequency does not conform to the input frequency.

2.3.19 *Hum Sidebands* — Undesired responses created within the spectrum analyzer appearing on the display that are separated from the desired response by the fundamental or harmonic of the supply frequency.

2.3.20 *Noise Sidebands* — Undesired response caused by noise internal to the spectrum analyzer appearing on the display around a desired response.

2.3.21 *Residual Response* — A spurious response in the absence of an input signal.

NOTE — Noise and zero pip are not to be considered as residual responses.

2.3.22 *Intermodulation Rejection* — The difference in decibels between the level of two equal magnitude input signals which produce any intermodulation product indication at the sensitivity level, and the sensitivity level.

2.3.23 *Input Impedance* — The impedance at the specified input terminal.

NOTE — Usually expressed in terms of swr, return loss, or other related terms for low impedance devices and resistance-capacitance parameters for high impedance devices.

2.4 Terms Related to Digital Storage

2.4.1 *Digitally Stored Display* — A display method whereby the displayed function is held in a digital memory. The display is generated by reading the data out of memory.

2.4.2 *Digitally Averaged Display* — A display of the average value of digitized data computed by combining serial samples in a defined manner.

2.4.3 *Multiple Memory Display* — A digitally stored display having multiple memory sections which can be displayed separately or simultaneously.

2.4.4 *Clear* — Pre-sets memory to a prescribed state, usually that denoting zero.

2.4.5 *Save* — A function which inhibits storage update, saving existing data in a section of memory (for example, ' save A ').

2.4.6 *View* — Enables viewing of contents of the chosen memory section (for example, ' view A ' displays contents of memory A).

2.4.7 *Maximum Hold* — Digitally stored display mode which, at each frequency address, compares the incoming signal level to the stored level and retains the greater. In this mode, the display indicates the peak level at each frequency after several successive sweeps.

2.4.8 *Scan Address* — A member representing each horizontal data position increment on a directed beam type display. An address in a memory is associated with each scan address.

2.4.9 *Volatile Storage* — A storage system where loss of the power to the system will result in a loss of stored information.

3. GENERAL TEST REQUIREMENTS

3.0 General — General test conditions and procedures shall be according to IS : 9176-1976* and the following data is based on it.

3.1 Statement of Limits of Errors

3.1.1 Limits of operating error (which apply under rated operating conditions) shall be stated.

3.1.2 Limits of intrinsic error (which apply under reference conditions) may be stated. In the absence of a statement, they are considered to be equal to the limits of the operating error.

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*Method for specifying the functional performance of electronic measuring equipment.

3.1.3 Limits of influence error may be stated. It is particularly useful to state these limits when one influence quantity or influencing characteristic causes an important part of the operating error. It may also be of interest to state that certain environmental conditions do not contribute to the operating error.

3.1.4 Limits of variation may be stated when this standard explicitly permits it.

3.1.5 Limits of stability error (drift) may be stated by the manufacturer either for the maximum time interval within which limits of operating error are not exceeded or the limits of this error together with the relevant time interval. The time intervals shall conform to this standard or be chosen in accordance with **4.3.4** of IS : 9176-1979*.

3.2 Performance to be Verified and Checked — The tests described in this standard are to be performed in order to verify compliance with the manufacturer's stated data. Test procedures are given in **4**.

3.3 Combinations of a Mainframe with Plug-ins — When a mainframe can take one or more plug-in devices, the assembly comprising the given plug-in devices and the mainframe itself is considered as a whole and shall comply with relevant requirements for errors and variations, as stated in the following clauses. When another plug-in device is substituted, the new assembly shall also comply with the relevant requirements for error and variations.

3.4 Reference Waveforms — Individual reference waveforms are designated in the specific test described in **4**.

3.5 Conditions for Test Location — Unless otherwise specified in this standard, the following conditions shall be maintained in the test location:

a) Temperature within the range of 15 to 35°C;

b) Relative humidity within the range of 45 to 75 percent;

c) Air pressure within the range of 70 to 106 kPa, and

d) The spectrum analyzer shall be operated with the rated values of supply voltage and frequency.

NOTE — The values indicated above should not be confused with those indicated in **3.11** for reference conditions and test conditions.

3.6 Type Tests

3.6.1 The tests specified in the following clauses are type tests applicable to spectrum analyzers ready for use, that is, with covers and accessories fitted, if necessary.

*Method for specifying the functional performance of electronic measuring equipment.

3.6.2 When carrying out type tests, each spectrum analyzer tested shall be subjected to each of the tests laid down in this standard, as applicable, and as agreed between the manufacturer and the user.

3.6.3 In general, measurements for verification shall be carried out with instruments which do not appreciably (or only calculably) affect the values to be measured. In principle, the errors in measurements made with these instruments should be negligible in comparison with the errors to be determined.

3.6.4 When the error of the instrument is not negligible, the following rule shall apply. If a spectrum analyzer is claimed to have a limit error of $\pm e$ percent, for a given performance characteristic and the manufacturer uses for its checking an apparatus resulting in an error of measurement of $\pm n$ percent, the error being checked shall remain between the limits $\pm (e - n)$ percent, likewise if a user checks the same spectrum analyzer using another apparatus resulting in an error of measurement of $\pm m$ percent, he is not entitled to reject the spectrum analyzer if its apparent error exceeds the limits of $\pm e$ but remains within the limits of $\pm (e + m)$ percent.

3.7 General Conditions for Test Purposes — Tests are carried out under the conditions given in **3.8** and **3.9** below and, if agreed between manufacturer and user, under that combination of conditions which may be expected to result in the maximum operating errors.

3.8 Standard Values and Ranges of Influence Quantities

3.8.1 The reference values or ranges, the rated ranges of use and the limit ranges of operation, storage and transport for all influence quantities shall be stated and shall be selected by the manufacturer from one of the usage groups, I, II or III in **6** of IS : 9176-1976*. Any exceptions to the values given, there shall be explicitly and clearly stated by the manufacturer with an indication that they are exceptions.

3.8.2 The spectrum analyzer may correspond to one group of rated ranges of use for environmental conditions and to another group for mains supply conditions, but this must be clearly stated by the manufacturer.

3.9 Preparation for Tests — Before tests are performed, the following shall apply.

3.9.1 Adjustments, if any, shall have been performed according to the manufacturer's instructions.

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*Method for specifying the functional performance of the electronic measuring equipment.

3.9.2 Before being switched on, the spectrum analyzer shall be in equilibrium with the temperature and humidity of the ambient air.

3.9.3 The spectrum analyzer shall be operated at the rated value of supply voltage for a period equal to the warm-up time as indicated by the manufacturer.

In the absence of any indication, this period shall be one hour.

3.9.4 After the warm-up time, further adjustment may be made by means of the appropriate controls in accordance with the manufacturer's instructions.

3.10 Particular Conditions — The controls shall be set and signals applied to the input, as indicated at the head of each of the applicable clauses.

When no indication is given for a control setting, it may be set to any suitable value. Unless otherwise specified, no signal is applied.

3.11 Reference Conditions — For the purpose of tests on spectrum analyzers, a selection of influence quantities and influence characteristics with their reference values and/or ranges is given in Table 1. The values have been taken from **6** of IS : 9176-1979*.

4. TEST PROCEDURES

4.0 In each of the following tests the results shall fall within the range of the manufacturer's stated values.

4.1 Display Frequency — Centre a known, stable test signal on the display. Using a frequency counter or some external means, accurately measure the frequency of the test signal. Readjust the centre frequency tuning control of the spectrum analyzer so as to re-centre the display. The variation of the centre frequency indicated by the spectrum analyzer to the known input frequency is the display frequency error.

The manufacturer shall state when the display frequency is the centre frequency.

4.2 Frequency Span — Frequency span accuracy is measured by displaying a quantity of equally spaced (in frequency) markers across the frequency span and observing the positional deviation of the markers from an idealized sweep as measured against a linear graticule. The positional deviation of the markers shall meet the frequency span accuracy specification.

*Method for specifying the functional performance of electronic measuring equipment.

TABLE 1 REFERENCE CONDITIONS

(*Clause* 3.10)

INFLUENCE QUANTITIES OR INFLUENCE CHARACTERISTICS	REFERENCE CONDITIONS		TOLERANCE ON REFERENCE VALUES PERMITTED FOR TESTING PURPOSES
	When the reference conditions are indicated	In the absence of indication	
(1)	(2)	(3)	(4)
Ambient temperature	20°C, 23°C 25°C, 27°C	25°C	± 2°C
Ambient air relative humidity	45 to 75 percent		
Air pressure (altitude)	101·3 kPa		
Supply voltage	Rated value		± 1 percent for dc and ac rms ± 2 percent for ac peak
Frequency of ac supply	Rated value		± 1 percent
Waveform of ac supply voltage	Sinusoidal		Difference between $\sqrt{2}$ times the rms value and peak value to within ± 1 percent
Waveform of triggering voltage	Sinusoidal		
Ripple content of dc voltage	Value given by the manufacturer	Negligible	

4.3 Frequency Linearity Error — Connect a precision frequency comb generator to the input of the spectrum analyzer. Using the centre frequency tuning control on the spectrum analyzer, centre in turn each comb line on the display. Alternatively adjust the comb generator to centre each comb line on the display. The difference of the differences between the frequency indicated by the analyzer and the known frequency of the comb line is the frequency linearity error.

4.4 Frequency Drift — Centre a known stable signal on the display. Conduct test, that is, wait a specified period of time. Re-centre the signal by tuning the signal generator. The change in signal generator frequency related to the measurement time is the drift.

The measurement time shall be one hour unless otherwise specified by the manufacturer.

4.5 Residual FM (or Incidental FM) — The test method measures residual FM by using the spectrum analyzer IF filters as an FM slope detector.

A signal of known low residual FM is applied to the spectrum analyzer. In some cases the local oscillator feed-through (zero pip) can be used as the signal. The signal is observed in linear display law with a resolution bandwidth approximately ten times greater than the anticipated peak-to-valley residual FM. With the signal level adjusted for full scale deflection, the frequency span is adjusted such that the skirts of the displayed IF filter shape form a convenient angle with the horizontal. The slope in an approximately linear region is then calculated in terms of vertical divisions per horizontal division and the frequency span is 1 kHz for a division, the slope is one vertical division per kilohertz (kHz).

The analyzer is tuned such that the known slope region of the skirt is placed midscreen and is then switched to zero span. The peak-to-valley variations of the horizontal trace divided by the slope is the residual FM.

NOTE 1 — The residual FM observed will depend on the duration of the skirt is placed midscreen and is then switched to zero span. The peak-to-valley variations of the horizontal trace divided by the slope is the residual FM.

NOTE 2 — For the purpose of this standard " short term " means measurements made for a period of time, specified by the manufacturer. The recommended time duration is 20 s to 20 μs per division. This will accommodate incidental FM from less than 1 Hz to tens of kilohertz (kHz).

4.6 Impulse Bandwidth

4.6.1 *Test Method 1* — Apply a signal of calibrated spectrum amplitude (volts per hertz or decibels above 1 V/Hz) to the input of the spectrum analyzer. Determine the display amplitude in volts [a signal into 50 Ω that produces a display of – 47 dB (1 mW) is about 1 mV]. The ratio of the amplitude in volts to the spectrum amplitude level in volts per hertz is the impulse bandwidth.

NOTE 1 — For example, a display level of 1 mV with a spectrum amplitude of 60 dB above 1 μV/MHz (1 mV/MHz) gives an impulse bandwidth of 1 MHz.

NOTE 2 — Spectrum analyzers with wideband front ends and spurious responses may respond incorrectly. A bandpass filter with a passband that is greater than the resolution bandwidth of the spectrum analyzer can be inserted between the impulse generator output and the input to the spectrum analyzer, to eliminate this problem. The insertion loss of the filter should be considered when determining the impulse bandwidth.

Spectrum analyzer front ends are susceptible to damage when driven by high-level pulse trains. Impulse generators generating pulses of some hundreds of volts should, therefore, be avoided. Manufacturers' recommendations for maximum input power should be followed.

4.6.2 *Test Method 2* — Apply a burst (pulsed RF) to the spectrum analyzer assuring that the pulse rate, f_p is less than one-fifth the approximate impulse bandwidth to be measured ($5f_p \leqslant B_I$).

It is also necessary that the pulse width; t_0, be narrow in relation to the bandwidth ($t_0 B_I \leqslant 0{\cdot}1$) but wide in relation to the carrier frequency (f_0) being pulsed ($f_0 t_0 > 15$).

The spectrum amplitude density display of the spectrum analyzer at the carrier (f_0) frequency is S_0 (ω).

Reduce the spectrum analyzer resolution bandwidth by a factor of five to ten times. Set the pulse repetition rate, f_p to be greater than the new resolution bandwidth. The display will consist of discrete Fourier components at the carrier frequency, f_0, and sidebands at the pulse rate (f_p) apart. Adjust the pulse rate, f_p, so that the carrier component, C_0, has the same display amplitude as the spectrum amplitude density, S_0 (ω), obtained previously.

The impulse bandwidth, B_I is then equal to the pulse rate, f_p ($B_I - f_p$).

NOTE — The technique is based on the fact that for an RF burst with a good on/off ratio (over 50 dB)

$$\frac{S_0 (\omega) f_p}{C_0} = B_I$$

4.7 Dynamic (Displayed) Resolution — Apply two variable frequency, equal amplitude cw signals through a combiner to the input of the spectrum analyzer. Adjust the frequency of the two signals so that their responses appear on the screen, then adjust the separation between signals so that their responses merge with a 3 dB notch between them. (The amplitude, of the two responses shall be equal.) The frequency difference between the signals is the dynamic resolution.

NOTE — Use of the spectrum analyzer video filter, if available, will aid in observing the 3 dB notch.

4.8 Dynamic (Displayed) Skirt Resolution — Apply two variable frequency and amplitude cw signals through a combiner, to the input of the spectrum analyzer. Adjust the frequency of the two signals so their responses appear on screen. Adjust the amplitude difference between the two responses to specifications (for example, 60 dB). Adjust the frequency separation between the signals so their responses merge with a notch that is −3 dB from the peak of the lower amplitude response.

The signal separation is the skirt resolution.

NOTE 1 — Use of the spectrum analyzer video filter, if available, will aid in observing the 3 dB notch.

NOTE 2 — The scanning velocity has a major affect on the resolution. Frequency span and sweep time should be specified for those instruments that do not have an " uncalibrated " indicator.

4.9 Static (Amplifiers) Resolution Bandwidth — Display law, whether linear, square or logarithmic shall be specified.

4.9.1 *Test Method 1* — Centre a known stable constant amplitude test signal on the display, adjusting the amplitude of the response to a reference level. Tune the signal generator until the leading edge of the response is down by the specified amount at the display centre. Measure the generator frequency. Repeat for the trailing edge of the response curve. The difference in the frequency measured is the resolution bandwidth.

4.9.2 *Test Method 2* — If manual scan is available on the analyzer, an external frequency counter and signal generator can be used to measure resolution bandwidth as the difference frequency for the two dot positions corresponding to the specified decibel down points.

NOTE 1 — Test Method 2 is the preferred method due to its greater accuracy.

NOTE 2 — The sweep time should be kept sufficiently long so as not to affect the measurement.

4.10 Shape Factor — Measure the frequency difference between the two specified points using the same test method as for resolution bandwidth.

NOTE — For consistency in specification, the same points may be specified for various resolution bandwidths even though it may not be possible to actually measure down that far on the curve, due to the noise floor of the analyzer, noise sidebands of the first local oscillator, or other such factors. In such a case, it is permissible to measure the wider frequency difference at a convenient point on the upper portion of the response curve and make an asymptotic extrapolation to the specified point.

4.11 Deflection Coefficient — Apply a calibrated cw signal, through a calibrated variable attenuator, to the input of the spectrum analyzer. Adjust the signal input level so that the resultant indication is that specified (for example, full scale). Note this input signal level (volts, decibels, watts, etc). Increase the attenuator setting until the deflection amplitude of the output indication is reduced to the desired degree (for example, half screen). Note the amount of attenuation required. The ratio of input signal amplitude reduction, in appropriate units, to the divisions of output indication change is the deflection coefficient.

NOTE 1 — For example, an input signal level change of 8 dB for four divisions of output indication change gives a deflection coefficient of 2 dB per division.

NOTE 2 — The manufacturer should state whether the specified deflection is an average or refers to a specific position on the indicator (for example, the graticule on a CRT).

4.12 Input Signal Level Sensitivity — Set the gain of the spectrum analyzer so that the internally generated noise produces a reasonable display indication of noise (for example, one division). Apply a constant amplitude cw signal generator with a calibrated output and adjust the level so the output signal indication is twice the value of the average noise level (for example, two divisions in linear). The spectrum analyzer sensitivity is equal to the output level of the signal generator [for example, 1 μV across 50 Ω or -107 dB (1 mW)].

NOTE — Noise indications depend on many parameters and operational functions, such as bandwidth and display law. The manufacturer should specify all parameters and functions that are important for this measurement.

4.13 Equivalent Input Noise Sensitivity — Set the gain of the spectrum analyzer so that the internally generated noise produces a reasonable display indication of noise (approximately one division). Determine the average noise level referred to the input by the spectrum analyzer reference level and deflection coefficient settings. The measured noise level is the equivalent input noise sensitivity.

NOTE — The use of a video filter, if available, is recommended as an aid in determining this average level. A noise floor of one division on an eight division graticule scale, with -50 dB (1 mW) level and 10 dB per division deflection coefficient is equivalent to -120 dB (1 mW).

Use a signal generator with a calibrated output to establish a reference output indication for those spectrum analyzers that are not calibrated.

4.14 Peak-to-Valley Display Flatness — Set the frequency span to the value specified. Centre a known stable test signal on the display. Adjust the amplitude to an arbitrary reference level on the screen. Vary the

frequency of the test signal so as to move the displayed signal over the frequency span. The peak-to-valley variation of the displayed amplitude shall meet the peak-to-valley display flatness specification.

NOTE — The measurement considerations laid down in **4.16** shall be taken into account.

4.15 Relative Display Flatness — The test method is the same as for **4.14** except that the reference level shall be specified by the manufacturer. The results are stated as a plus and minus deviation with respect to the specified reference level.

4.16 Peak-to-Valley Frequency Response — Centre a known stable test signal on the display. Adjust the amplitude to a reference level on the screen. Vary the frequency of the constant amplitude test signal over the frequency range. At each setting readjust the centre frequency tuning of the spectrum analyzer so as to centre the display. The peak-to-valley variation of the displayed amplitude shall meet the peak-to-valley frequency response specifications.

NOTE 1 — This measurement can be made at any convenient frequency span, resolution bandwidth, display law and deflection coefficient. Since small variations in displayed amplitude are to be expected, the most sensitive deflection coefficient shall preferably be chosen.

NOTE 2 — Of special importance to this test method is the flatness of the amplitude of the test signal over the frequency range. The flatness of the test signal shall be carefully measured using an appropriate power meter or voltmeter prior to conducting the frequency response test on the spectrum analyzer. A correction factor for the test signal flatness shall be included, if necessary.

In monitoring the test signal amplitude, consideration shall be given to the possibility of power being emitted from the input port of the analyzer, such as the first local oscillator emission. If power is emitted from the input port of the analyzer, the flatness of the test signal shall be measured separately or directional couplers or other means be used to prevent the emitted power from giving a false measurement of the test signal power.

4.17 Relative Frequency Response — The test method is the same as for **4.16** except that the reference level is to be specified by the manufacturer. The results are stated as a plus and minus deviation with respect to the reference level.

4.18 Display Law

4.18.1 *Linear Display Law* — Apply a cw signal through a calibrated variable or step attenuator to the input of the spectrum analyzer. Adjust the signal voltage level so that the displayed output indication is full scale.

Decrease the input signal voltage with the attenuator, in a sequence of known ratios or percentages (for example $\frac{1}{2}$, $\frac{1}{4}$). The amplitude of the displayed output shall decrease by the same proportion ($\frac{1}{2}$ scale, $\frac{1}{4}$ scale, etc).

4.18.2 *Square Display Law* — Apply a cw signal through a calibrated variable or step attenuator to the input of the spectrum analyzer. Adjust the signal power level so the displayed output indication is full scale. Decrease the input signal power, with the attenuator in a sequence of known ratios or percentages (for example, $\frac{1}{2}$, $\frac{1}{4}$). The amplitude of the displayed output shall decrease by the same proportion to the known ratios or percentages.

4.18.3 *Logarithmic Display Law* — Apply a cw signal through a calibrated variable or step attenuator to the input of the spectrum analyzer. Adjust the signal level so the displayed output indication is full scale. Decrease the input signal level with the attenuator in decibel increments (for example, 2 dB, 10 dB, etc). The amplitude of the displayed output shall decrease in proportion to the logarithmic deflection factor (for example, the amplitude of display will reduce the one division for a 2 dB increment when the deflection coefficient is 2 dB/div).

The difference between the measured deflection coefficients shall meet the specified display law accuracy.

4.19 Harmonic Dynamic Range

4.19.1 *Test Method 1* — Apply a harmonically pure cw signal to the input of the spectrum analyzer. Increase the input signal level until a harmonic response appears at the sensitivity level. This is the maximum input level for harmonic measurement.

The difference, expressed in decibels, between the maximum signal input level and the spectrum analyzer sensitivity level, is the harmonic dynamic range [for example, -20 dB (1 mW) maximum input signal level with a spectrum analyzer sensitivity of -100 mW (1 mW) equals 80 dB of harmonic dynamic range].

NOTE — The use of a low-pass or band-pass filter is a good way to reduce the harmonic content of the signal source.

4.19.2 *Test Method 2* — The following technique may be utilized when a harmonically pure signal source is not available:

Apply a cw signal to the input of the spectrum analyzer. Note the difference ΔL (in decibels) between the display amplitude of the fundamental and second harmonic. Increase the input level until the second harmonic display amplitude increases at twice the decibel rate of the fundamental (for example, a 10 dB increase in fundamental input level produces a 20 dB increase in the second harmonic level).

Note the fundamental input signal level (L) and the difference between the fundamental input signal level and second harmonic display level (ΔL). The harmonic dynamic range (D_L) is related to instrument sensitivity (L_{min}), fundamental signal level (L_1) and difference between fundamental and second harmonic level (ΔL) as follows:

$$D_L = \frac{L_1 + \Delta L - L_{min}}{2}$$

Example : $L_1 = -10$ dB (1 mW), $\Delta L = 20$ dB, $L_{min} = -100$ dB (1 mW), and $D_1 = 55$ dB.

NOTE — Keep L_1 below the maximum input power to avoid instrument damage. The method based on a spectrally pure signal source is preferred. Test Method 2 is less accurate since it considers only quadratic non-linearity terms.

4.20 Non-harmonic Dynamic Range — Apply two signals whose frequencies are not harmonically related, with calibrated and variable amplitude levels, through a matched combiner, to the input of the spectrum analyzer. Set the level of one signal at the sensitivity level of the spectrum analyzer [for example, -100 dB (1 mW)]. Increase the level of the second input signal until the accuracy of the amplitude ratio between the two responses is in error by the specified amount, or until the low level signal is obscured by gain of desensitization, spurious responses, noise sidebands, or other effects. This is the maximum input level for non-harmonic measurement. The difference in decibels, between the maximum signal input level and the spectrum analyzer sensitivity level, is the non-harmonic dynamic range.

NOTE 1 — For example, a $+10$ dB (1 mW) maximum input signal level with a spectrum analyzer sensitivity of $-$ 100 dB (1 mW) equals 110 dB non-harmonic range.

NOTE 2 — The manufacturer shall specify the frequency separation of the signals.

4.21 Display Dynamic Range — Apply two signals that are not harmonically related, with calibrated and variable amplitude levels, through a matched combiner, to the input of the spectrum analyzer. Set the level of one signal at the sensitivity level of the spectrum analyzer. Increase the level of the second input signal until its response is either full screen or until the low level signal is obscured. This is the maximum input level for display dynamic range measurement. The difference, in decibels, between the maximum input level [for example, -30 dB (1 mW) and the spectrum analyzer sensitivity {$-$ 100 dB (1 mW)}] is the display dynamic range.

NOTE 1 — For example, a maximum input signal level of $-$ 30 dB (1 mW) with a spectrum analyzer sensitivity of $-$ 100 dB (1 mW), equals a display dynamic range of 70 dB.

NOTE 2 — The manufacturer should specify the frequency separation of the signals.

4.22 Gain Compression — Apply a cw signal to measure the display law accuracy in accordance with **4.18**. Increase the input signal level till the display law accuracy error (scale linearity error) increases to the specified level of accuracy. This is the gain compression level.

4.23 Hum Sidebands — Apply a known pure signal to the spectrum analyzer and set the frequency span and resolution to resolve the hum sidebands (resolution bandwidth less than the supply frequency). The level of each of the hum sidebands is measured relative to the level of the main response. The amplitude difference, in decibels, shall meet the hum sidebands specifications.

4.24 Noise Sidebands — Apply a stable signal to the spectrum analyzer and set the frequency span, resolution and display law as specified. Note the amplitude of the noise sidebands at the specified frequency separations from the desired response and compare to the amplitude of the desired response. The amplitude differences, in decibels, shall meet the noise sidebands specifications.

NOTE — Use of a post-detection smoothing filter (for example, video filter) will help in the observation of the noise sidebands.

4.25 Residual Response — Terminate the input of the spectrum analyzer and examine all possible frequencies for responses.

Likely occurrences are the fundamental and harmonics of internal local oscillator frequencies and frequencies near the zero pip.

The spectrum analyzer control settings will affect the results of this test and shall be noted. All such responses except zero pip are residual.

4.26 Intermodulation Rejection — The test is performed by combining the outputs of two signal generators using a directional coupler or other suitable means. The most important consideration for the combiner is high isolation between the signal generators to prevent significant intermodulation distortion in the signal generators. At microwave frequencies it is recommended that an isolator be used at each generator output, and a 3 dB coupler for a combiner.

The combined signal is applied to the spectrum analyzer and the level of each generator increased synchronously until sidebands on either side of the main responses appear wlth a unity signal to noise ratio. The intermodulation rejection is the ratio of the level of one of the two equal test signals to the noise level.

NOTE — One can verify that the intermodulation sidebands are due to the analyzer and not intermodulation in the generators by the following:

> Increase the level of test signals until the sidebands are well out of the noise. Insert attenuation between the output of the combiner and the input of the spectrum analyzer. If the intermodulation is taking place in the spectrum analyzer, the sidebands should drop in logarithmic level *n* times as much as the test signal drop where *n* is the order of the distortion. For example, 3 dB attenuation will drop the test signals 3 dB and the third order sidebands by 9 dB resulting in a 6 dB increase in the difference of levels.

If the intermodulation was occurring in the generators, both the sidebands and the test signals will decrease by 3 dB and the difference will remain the same.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	st

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2